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COOLING MILK ON THE FARM WITH SMALL MECHANICAL OUTFITS

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INTRODUCTION

Mechanical refrigeration is used extensively in milk plants and other city establishments for cooling and storing milk and cream. Likewise, in the past 5 years the use of mechanical refrigeration for cooling and storing milk on dairy farms has increased rapidly. Many small refrigerating machines are on the market, similar in mechanism to those used in small milk plants, stores, and household refrigerators, and suitable for use on farms where electric current is available. Some units using kerosene burners and gasoline engines for power are also available. These machines can be obtained in almost any size desired, with or without the storage unit.

To obtain definite information on what may be expected by dairy farmers in general from small refrigerating machines, a study was made at 44 dairy farms in Maryland and Virginia where mechanical outfits of various types using electric current as power have been installed. The amount of milk handled ranged from 15 to 200 gallons per day per farm. Data were obtained on methods of arrangement and operation, power consumption, cost of equipment and repairs, and efficiency of the different outfits in comparison with each other and with equipment in which ice was used. The results are presented and discussed in this circular, with suggestions for effective arrangement and operation. Plans are also included for an inexpensive homemade storage tank or refrigerator box, depending on which is to be used with the machine. Such a tank or box, if properly constructed, is as efficient as and often cheaper than one shipped in from a factory.

PURPOSE OF COOLING MILK

Milk, when drawn from the udder, offers both an ideal food and a culture medium at optimum temperature for the development of many kinds of bacteria. Unless bacterial growth is checked, undesirable fermentation may take place in the milk causing off flavors and odors or souring, and thereby preventing its use for market purposes. After the milk is produced, cold is the chief factor used on the farm to check growth of bacteria in it. For example, in one experiment milk with a bacterial content of 16,000 per cubic centimeter kept sweet for about 36 hours when held at a temperature of 75° F., 80 hours when held at 55°, and 180 hours when held at 40°. Bacterial off flavors may develop at any temperature but they develop more rapidly at the higher temperatures. In other words, cooling delays changes in the milk which affect quality and palatability and helps to maintain its original quality. Therefore it is of the utmost importance that milk be promptly cooled to and stored at a temperature of 50° or lower.

No means of cooling will offset carelessness in production and handling, however. The same attention to sanitation in these matters should be given when mechanical refrigeration is used as is necessary with any other means of cooling.

MEANS USED IN COOLING MILK

On farms three means are employed for the cooling of milk, namely, water, ice (either natural or artificial), and mechanical refrigeration.

Water from wells, springs, or supply tanks, even under the best conditions, is usually not cold enough to cool the milk below 50° F. in warm weather, and there are difficulties in using water alone for storage of milk, so that its use is limited. The use of ice or mechanical refrigeration is then the only means whereby milk can be cooled and stored on most farms during warm weather at temperatures low enough to check bacterial growth. Where ice is employed on the farm for cooling and storing milk, it is almost universal to use a tank wherein ice and water form the cooling medium. This type of storage is known as the wet tank. However, on producer-distributor farms where milk is bottled, dry-box storage with ice as the cooling medium may be used, but on other types of farms this system is not so practical.

The use of water and of ice for cooling milk on dairy farms is discussed more fully in Farmers' Bulletin 976, Cooling Milk and Cream on the Farm.

With mechanical units either wet-tank or dry-box storage can be used economically. Where wet storage is used with mechanical units, the evaporating coil[1] for absorbing the heat is placed in the water in the storage tank. Where dry storage is used the cooling medium is usually a brine solution confined in an iron or copper tank within the storage box. The evaporating coil is located in the brine tank, and by absorbing heat from the brine keeps it chilled. In wet storage there are only two transfers of heat, namely, from the milk to the water in the storage tank, and from the water to the coils; whereas in dry storage there are three transfers of heat, that is, from the milk to the air in the box, from the air to the brine solution, and from the brine to the coils.

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[1] So-called because in it the refrigerant is permitted to evaporate in order to absorb heat from the surrounding water or air (p. 4).

FACTORS INFLUENCING THE USE OF REFRIGERATING MACHINES

The rapid increase in the use of refrigerating machines on dairy farms is due chiefly to (1) improvement in the machines, (2) the extension of electrical lines into the country, (3) irregular deliveries of ice, (4) saving in labor, and (5) regulations of health departments.

Manufacturers of refrigerating machinery have made great progress in recent years in developing the small self-contained compression machines which are almost universally used for small-scale mechanical refrigeration. The principal parts of such a machine are the compressor and motor, condensing coils, evaporating or cooling coils, and the storage tank or box. In the machines much improvement has been made in the compressor, the expansion valve, and the thermostatic control.

The rapid extension of electrical lines into the country has made the use of refrigerating machines possible on many farms. In 1924 only about 2.7 percent of the farms in the United States were served with high-line electricity; in 1932 this had increased to 11 percent.

In sections where farmers depend for their ice supply upon manufactured ice, irregularity of delivery has turned many to the use of refrigerating machines. From 1917 until a few years ago farm laborers were difficult to secure. As a result any machine that would lessen the farmer's manual labor was a welcome addition to the farm.

Health-department regulations also have been an important factor in influencing a change in refrigerating methods. In most markets over which public-health authorities have control it has been the practice to set a maximum temperature for the milk when it reaches the city market. This temperature in some cities is as low as 40° F. Although these temperatures are attainable with ice, an abundant supply must be present at all times. The ice takes up extra room in the tank, and the dairyman must keep a watchful eye to see that the amount is sufficient to maintain the temperature desired. Mistakes in judging the right amount of ice may lead to a poor-quality milk.

TYPES OF REFRIGERATING MACHINES STUDIED

The refrigerating machines observed under actual working conditions and discussed herein were compression machines, all driven by electric motors. All machines worked on the same principle, although sulphur dioxide, methyl chloride, or ammonia were used to accomplish refrigeration in different machines.

The term " refrigeration " is used to denote extraction of heat from anything, and most commonly in connection with lowering the temperature of a thing below ordinary air or room temperature. Mechanical refrigeration is accomplished almost universally by alternately vaporizing and condensing a volatile liquid. Ammonia, sulphur dioxide, methyl chloride, and similar volatile liquids evaporate at ordinary room temperatures when not under pressure, but condense again into liquid form when compressed and cooled to room temperatures. The liquid is permitted to evaporate in the coil in the brine or cooling tank, and in doing so it absorbs heat from the surrounding water or air. The gas is then compressed, cooled by air or water circulating around the condensing coils, and becomes a liquid. It is then in condition to be evaporated again, and absorb more heat from the tank or box to be refrigerated.[2]

COST OF OUTFITS

The cost of outfits was obtained on 32 farms. On 23 of these farms a complete outfit had been purchased, including the mechanical unit (comprising the compressor and its motor), a manufactured cooling tank or box, coils, and a circulating pump with its motor. In this group the cost of the complete outfit per cubic foot of storage capacity averaged $16.56 and ranged from $10.40 to $30.50 per cubic foot. Eleven outfits, or 48 percent of those in this group, cost between $10 and $15 per cubic foot, and 8 outfits, or 35 percent, cost between $15 and $20 per cubic foot.

In 9 cases no tank or box was purchased with the outfit, and the cost of the tank or box was not obtained. For this group the average cost of the mechanical outfit per cubic foot of storage space was $13.45, with a range from $8.80 to $21.20. For 6 plants, or 66 percent of this group, the cost was between $8 and $15 per cubic foot of storage.

In table 1 the cost of the complete outfits is figured on the basis of rated storage capacity per 10-gallon can. It is interesting to note in this tabulation that the average price per outfit increases as the size of the machine increases, but the price per 10-gallon can of storage capacity decreases as the size increases.

TABLE 1.—*Cost of 23 mechanical outfits*[1] *arranged according to rated storage capacity per number of 10-gallon cans*

Number of farms	Rated storage capacity	Price range—complete outfit	Average price	
			Per outfit	Per 10-gallon can
	10-gallon cans	*Dollars*	*Dollars*	*Dollars*
7	4	350–500	410	103
7	6	328–700	481	80
6	8	485–635	554	69
2	10	510–550	530	53
1	14	675	675	48

[1] These outfits were purchased during the period 1928 to 1931, inclusive.

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[2] For more complete information on principles of refrigeration, see the following publication: BOWEN, J. W. REFRIGERATION IN THE HANDLING, PROCESSING, AND STORING OF MILK PRODUCTS. U.S. Dept. Agr. Misc. Pub. 138, 59 pp., illus. 1932. This publication may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D.C., for 10 cents.

With the nine outfits where no tank or box was purchased, there were an insufficient number to tabulate in the above manner. However, the average cost on these farms per 10-gallon can of storage capacity was about $62.

COST OF REPAIRS

The cost of repairs over a period of from 1 to 5 years was obtained on 19 farms. The machines had an average age of 2 years 8 months. The average cost for repairs was $4.20 per year. The repairs were of a varied nature, the more common being the regulation of the automatic switch, the replacing of worn belts, and the fixing of leaks that had developed in the coils so that new refrigerant had to be added. In one case the valves of the compressor had to be replaced. In some cases the firm selling the machine charged a flat service rate per year, for which a representative was to make as many trips as were required in order to keep the machine running. Any parts which had to be replaced were to be paid for by the owner.

INSTALLATION AND ARRANGEMENT

LOCATION OF THE MACHINE

On dairy farms mechanical units are installed in three locations, namely, in the same room as the milk-storage tank or box; in a separate room from the storage tank or box; or outside of the milk house, the machine being protected under a shedlike structure (fig. 1, *A*) or in some instances under a shed with lattice work on the sides (fig. 1, *B*). Of the 44 machines studied, 34, or about 77 percent, were in the milk room; 9, or about 20 percent, were in a separate room; and 1, or about 2 percent, was outside the building. Of the machines located in the milk room, about 54 percent was placed at the side of the storage box and 46 percent on top of the storage box.

After observing these machines under working conditions, the conclusion was reached that the mechanical unit of this type should be located in a well-lighted, well-ventilated room separate from the storage or milk-handling room for the following reasons: Nearly all these small machines are air-cooled. As soon as the dairyman starts cooling his milk, the thermostatic control starts the machine running with the result that any dust about the machine, in the room, or in the air pulled from outside by the fan, is circulated about. If the machine is in the milk room, some of this dust is apt to come in contact with the milk or the utensils in which the milk is handled. Another objection to having the machine in the milk room is that the machine generates heat, which is dissipated over the room and at times may raise the air temperature more than 6° F. This means that the machine must overcome this additional heat in cooling the milk. The machinery needs oil, and it is hard to use oil without dropping some. The older the machine the more oil leaks out. The dark area in figure 2 is due to the leakage of oil. Materials of this nature have no place in a milk room, especially on top of the storage tank.

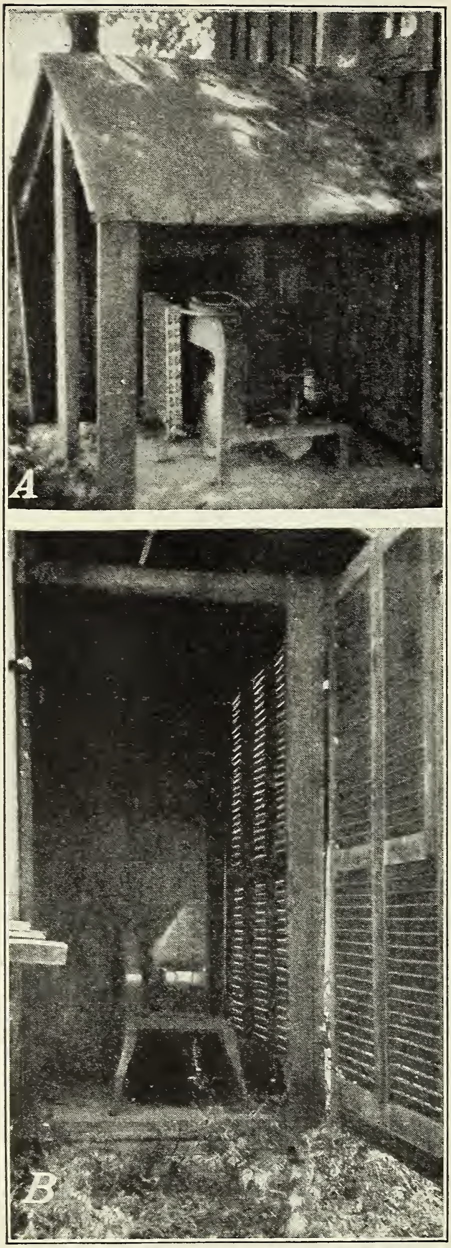

FIGURE 1.—Examples of machine located outside of the milk house and protected from the elements by (*A*) a small shedlike structure or (*B*) a shed with latticed sides.

SIZE OF STORAGE TANK OR BOX

It is important that the storage tank or box be of the proper size for the amount of milk to be handled. A good general rule would be to purchase a size sufficient to care for the maximum daily quantity of milk produced at any season of the year, and no larger. The economy of this can be shown by considering farm no. 4 (table 7) where it is possible to check the heat loss through the walls of the tank by the amount of ice that was melted per 24 hours.

One hundred and fifty pounds of ice was melted per 24 hours in cooling 101 gallons of milk through a range of 15° F., down to 46°, while holding the tank temperature at 37°. There were 12,706 British thermal units of heat removed from the milk and cans. Since it takes 144 British thermal units of heat to melt 1 pound of ice, the amount of ice used to cool the milk was 12,706 divided by 144, or 88.3 pounds of ice. The remaining 61.7 pounds of ice melted was used to overcome the heat loss from the tank. Stated as a percentage, 59 percent of the refrigeration was used in cooling milk and 41 percent to keep the tank cool. When under almost identical conditions an electric-powered mechanical unit was used, 8,857 watt-hours of power was consumed. Dividing this in the same proportions as was found for the ice, 5,226 watt-hours was used to cool the milk and 3,631 watt-hours to keep the tank cool.

The 12,706 British thermal units of heat removed in cooling the milk divided by 5,226 watt-hours used in cooling it, gives 2.43 British thermal units removed per watt-hour of power used.

On this farm, as is the general practice, the night's milk is cooled and stored and the morning's milk is cooled only, before shipping. The amount of power used for cooling and storing was 1,046 watt-hours per can cooled, not including the power for keeping the tank cool. With these figures, table 2 has been prepared to show the total amount of power required per can cooled for such an eight-can storage outfit when used to cool and store different quantities of milk.

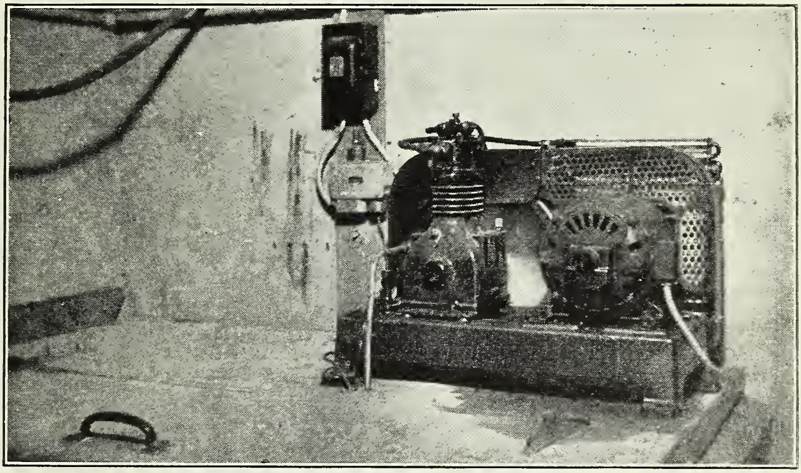

FIGURE 2.—Machine located on top of storage box. Note the dark area, which is due to oil from the machine.

TABLE 2.—*Approximate power requirements for an eight-can storage-tank outfit when used for cooling and storing different quantities of milk*

Power requirement per day	To keep tank cool	To cool—				
		4 cans; store 2 cans	8 cans; store 4 cans	10 cans; store 5 cans	12 cans; store 6 cans	16 cans; store 8 cans
	Watt-hours	*Watt-hours*	*Watt-hours*	*Watt-hours*	*Watt-hours*	*Watt-hours*
Total	3, 627	5, 719	7, 811	8, 857	9, 903	11, 995
Per can produced	------------	1, 430	976	886	825	750

The table shows that when cooling 4 cans per day the power required is 1,430 watt-hours per can, and when cooling 16 cans the requirement is but 750 watt-hours per can produced. In other words, if the tank or box purchased is too large, the additional cost of electric current to supply the heat lost through the walls will soon amount to more than the advantage of the extra room.

SIZE OF COMPRESSOR REQUIRED

Approximately 0.0585 pound of ice-melting capacity is required to give 1 gallon-degree of refrigeration; that is, to cool 1 gallon of milk

1° F. Since in a well-constructed storage box used to capacity the milk-cooling load is equal to 70 percent of the refrigeration load and the heat loss 30 percent, the refrigeration required per gallon-degree in ice-melting capacity, or the melting-ice equivalent, as it is known in refrigeration, would be 0.084 pound[3] of ice-melting capacity. The capacity of the compressor needed can be found as follows: Multiplying the number of gallons of milk to be cooled per day by the number of degrees it is to be cooled by the refrigerating machine gives the total number of gallon-degrees; then multiplying the number of gallon-degrees by 0.084 gives the total ice-melting capacity needed per day. Dividing this amount by the number of hours the machine is to run each day, for example, 10 or 12 hours, will give the rating of the compressor needed, in pounds of ice-melting capacity or melting ice equivalent per hour.

The size of compressor needed for cooling and storing milk can be computed readily by multiplying the figures given in table 3, under the temperature range of cooling, by the maximum number of 10-gallon cans of milk to be cooled. The figures given under refrigeration required per day represent the total amount of ice required to cool 10 gallons of milk, while the compressor rating represents the capacity of compressor needed figured on a 12-hour running time per day.

Table 3.—*Compressor capacity required per 10-gallon can of milk to be cooled to and stored at 40° F.*

Range of cooling temperature (° F.)	Melting ice-equivalent— Per day of refrigeration	Melting ice-equivalent— Per hour of compressor rating
	Pounds	*Pounds*
10	8.4	0.7
20	16.8	1.4
30	25.2	2.1
40	33.6	2.8
50	42.0	3.5
60	50.4	4.2

LOCATION OF THE BRINE TANK IN STORAGE BOX

A number of the outfits studied had dry-storage boxes. When this type of storage is used with a refrigerating machine on the dairy farm, the most advantageous location of the brine container or tank is at the top of the storage box (fig. 8). Either copper, galvanized iron, or boiler plate may be used for constructing the brine tank; the last would probably be the cheapest. If boiler plate is used, a protective coat of red lead will prove very satisfactory. If the evaporating coils are of copper, a copper tank would probably prove more satisfactory, as it would eliminate electrolysis, which causes corrosion.

The brine can be made either of sodium chloride (common salt) or calcium chloride. The latter is generally used, as it has a lower freezing temperature with the same concentration. The quantity of brine required in the tank depends on the quantity of milk to be cooled daily, the desired cooling temperature, and the size and insulation of the box. However, as a general rule, with calcium chloride brine, one should figure on having about 1½ to 2 gallons of brine in the tank per gallon of milk cooled per 24 hours. In making up the brine, 2½ pounds of calcium chloride, with 1 ounce of lime for preventing electrolysis, should be added to each gallon of water. The average temperature of the brine usually used on dairy farms is 20° to 25° F.

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[3] For a tank or box that is poorly insulated, or is too large for the amount of milk to be cooled, a figure higher than 0.084 will be required.

LOCATION OF THE THERMOSTATIC CONTROL IN STORAGE TANK

In order to maintain a nearly constant temperature in the storage tank or box, all electrically operated machines are equipped with a thermostatic control. This device starts and stops the machine automatically whenever the temperature in the box or tank increases or decreases a few degrees above or below the desired temperature.

With wet-tank storage it is customary to circulate the cold-storage water through a milk cooler in order to cool the milk as quickly as possible before setting the cans of milk in the tank. At one farm the tank was so constructed that it was possible to change the location of both the cooler intake and the cooler outlet in the storage tank in relation to the control device. Three different arrangements were tried for a period of four milkings each; namely (1) with the cooler outlet at the far end of the tank and the cooler intake over the control; (2) with the cooler outlet and intake within 1 foot of each other and directly over the control; and (3) with the cooler intake at the far corner and the cooler outlet over the control. In arrangement no. 1 the average consumption of electric current per gallon-degree of refrigeration was 2.68 watt-hours, and the average period of time required for the compressor motor to start was 22 minutes after the water-circulating pump was started; in no. 2 the machine averaged 2.96 watt-hours and the compressor motor required 1.5 minutes to start; and in no. 3 the machine averaged 1.98 watt-hours and the compressor motor required 2.3 minutes to start.

In the absence of any data taken with instruments, such as measurements of water currents, temperature of box at all points, amounts of ice on coils before and after cooling, it is thought that this difference in watt-hours used per gallon-degree might be due to a better circulation of water in the tank, which helped to remove any accumulation of ice on the coils. It was noted that in arrangement no. 3 the coils were more free of ice at the end of the cooling period than they were in arrangement no 2.

These figures seem to indicate that the cooler outlet should be placed over the control, and that the cooler intake should be as far from the control as possible. However, with some machines there is a tendency to freeze considerable ice upon the top coils. In that case it is a good plan to extend the return pipe, with lengths of pipe having small holes drilled every few inches, around the inner periphery of the tank and just above the coils (fig. 3). This plan will help to keep the amount of ice at a minimum, and the return water from the milk cooler will be cooled much more quickly.

COILS IN STORAGE TANK

In wet-storage tanks three systems of installing coils in the tanks are used: (1) Bunched coils, made of pipe, placed in the center of the tank; (2) coils, made of pipe or radiator sections (fig. 4, *A*), arranged around the inner periphery of the tank; and (3) coils, made of pipe, placed on the bottom of the tank. Bunched coils are difficult to support adequately, and care must be taken that the cans of milk do not strike against them. Also, ice accumulates more readily on bunched coils than on coils of other types, because the coils are closer to each other and farther from the return water of the circulating pump. When the ice gets thick, as shown in figure 4, *B*, it acts as an insulation. Where coils are placed on the bottom or around the inner periphery of the tank, they should be adequately protected by a frame so that cans of milk will not come in contact with them.

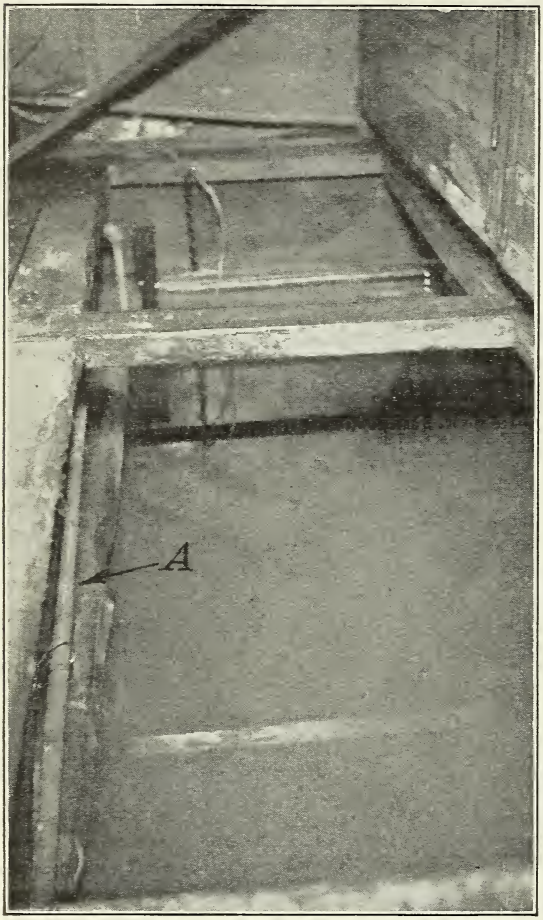

FIGURE 3.—Milk-storage tank with a perforated pipe (*A*) above the refrigerating coils, so that the return water from the milk cooler will help to melt the ice from the coils.

The coils were all one-half inch in diameter, with the exception of the outfit on farm no. 26. The length of coil used per cubic foot of tank space differed greatly in the different tanks observed. The length of coil in inches per cubic foot of total tank space is given for 20 farms in table 4. The range is from 20.9 to 60.6 inches per cubic foot of tank. Seven, or 35 percent of these, had from 20 to 30 inches of coil per cubic foot, and the same number had from 30 to 40 inches per cubic foot.

The proper length of cooling coil depends primarily on the design of the compressor and on the refrigerant used, although it is also influenced by the temperature range through which the milk is cooled. Since the compressor and the coils are part of the manufactured unit, the recommendation of the manufacturer for length of coils should ordinarily be accepted.

Farmers writing manufacturers for information regarding the selection of the proper size of refrigerating unit should give the following data: The maximum amount of milk to be cooled and stored per 24 hours at any one time; the range of temperature through which the milk is cooled, for example, from 95° to 40° F. if no well water is used; the temperature of the well water; and the thickness and kind of insulation in the tank.

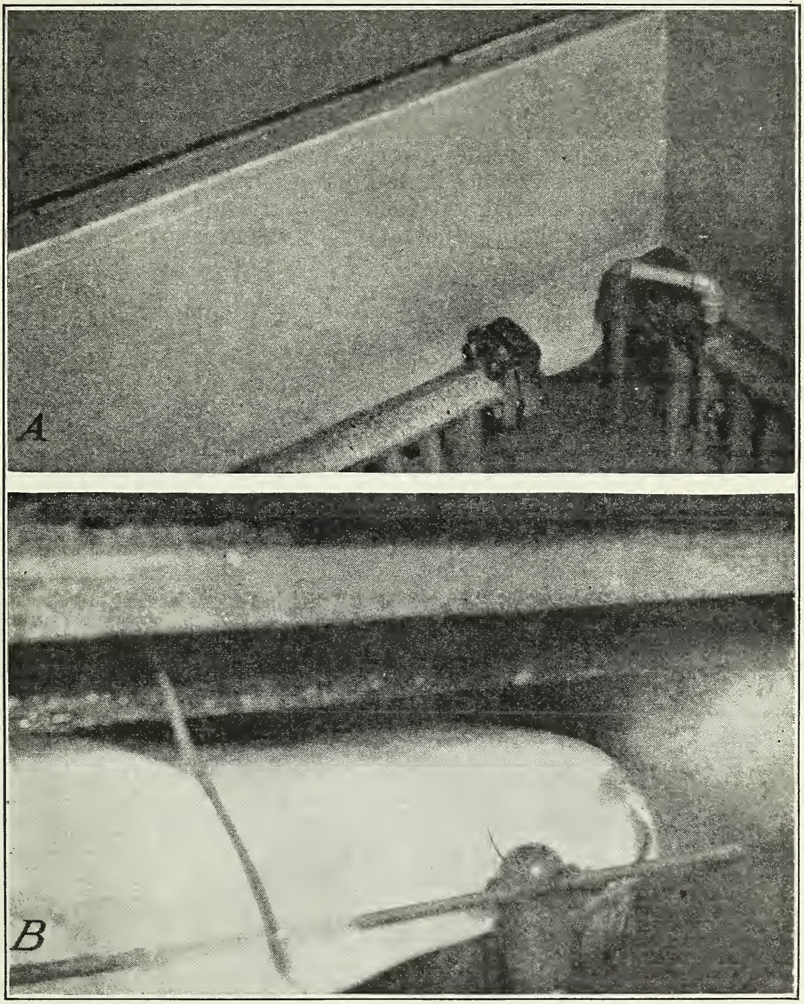

FIGURE 4.—*A*, Refrigerating coils, assembled from radiator sections, arranged around inner periphery of storage tank. Pipe is generally used for coils. *B*, An accumulation of ice on bunched coils, estimated to be 200 pounds.

LINE VOLTAGE IN RELATION TO MACHINES

The voltage of the power lines supplying the farms included in this study fluctuated greatly. Figure 5 shows examples of recorder charts of the best or most uniform and the poorest or most variable line voltages. As will be noted, the greatest fluctuation in voltage comes at about the time the milk is being cooled. No cases of motor damage due to too low or too high voltage were reported, and the efficiency of operation of the refrigerating units was not noticeably impaired. However, on one farm where the delivered voltage fluctuated widely, the use of the electric range when the demands on the line were heavy so reduced the voltage on the farm connection that the motor of the refrigerating unit would not start. This is a rare case and was probably due rather to a service connection that was too light than to the power-line voltage being too low.

CHANGING WATER IN STORAGE TANK AND AMOUNT USED

Data on the water used in mechanical refrigeration of milk on 22 farms having wet-storage tanks are given in table 4.

TABLE 4.—*Data from 22 farms showing size of storage tank, length of coils, amount of water in tank and amount per gallon of milk stored, rate of circulation through milk cooler, and interval between changes of water*

Farm no.	Size of tank	Length of coils per cubic foot of tank space	Amount of water in tank		Time required to circulate storage water once through cooler	Frequency of changing water		
			Total	Per gallon of milk stored		Interval between changes	Rise in tank temperature during change	Time required to reach original temperature
	Cu. ft.	*Inches*	*Gallons*	*Gallons*	*Minutes*	*Weeks*	*°F.*	*Hours*
1	26.8	38.1	83.1	2.8	9.0	8	8	4
2	20.4	38.2	65.5	8.2	16.0	14	--------	--------
4	38.4	31.8	133.7	2.6	--------	--------	--------	--------
5	24.6	46.8	58.7	4.2	17.0	4	--------	--------
6	49.8	22.8	167.1	4.3	25.0	8 to 12	--------	--------
7	25.2	41.7	95.0	4.0	14.0	24	--------	--------
8	25.2	20.9	84.3	2.8	10.0	8	--------	--------
9	28.2	27.3	94.6	4.3	35.0	16	--------	--------
11	28.7	60.6	115.2	5.0	36.0	4	20	8.0
12	28.3	--------	106.0	5.3	--------	12	--------	--------
13	36.0	27.2	115.5	3.2	31.0	8	28	24.0
14	36.3	44.6	114.0	1.9	35.0	2	24	11.5
15	63.8	34.8	214.6	5.4	23.0	4	--------	--------
16	33.7	29.6	158.1	2.3	23.0	1	15	7.5
17	26.7	41.9	84.0	4.2	--------	12 to 16	--------	--------
18	26.7	38.2	86.4	5.8	20.0	12 to 16	20	12.5
19	36.0	39.3	110.4	3.4	26.0	12 to 16	--------	--------
21	42.8	--------	144.8	6.6	--------	12 to 16	--------	--------
23	33.5	23.9	120.5	2.0	36.0	6	--------	--------
24	30.9	51.1	85.7	1.7	21.0	8	17	5.8
26	46.2	23.8	186.5	3.7	40.0	12	--------	--------
27	41.3	37.7	128.9	2.6	63.0	2	16	6.0

In this table attention is called to the frequency of changing the water in the storage tank. Of the 21 dairymen who reported changing water, 8, or nearly 40 percent, changed it every 12 to 16 weeks, and 9, or about 43 percent, changed it every 4 to 8 weeks. Observations indicated that care in keeping the cans and the milk room clean at all times saved frequent changing of the storage water. Some dairymen washed the outside of the cans before putting them into the storage tank. Where such care was taken the storage water was in excellent condition at the end of 5 months. The importance of not having to change the cold-storage water often can be seen by referring to the seventh, eighth, and ninth columns of table 4. The rise in temperature of the storage water when it was changed was from 8° to 28° F., and it required from 4 to 24 hours until the water again reached the original temperature. Not only is extra power required, but in cases where the machine is working nearly to capacity, the night's milk would not be stored at as low a temperature as desirable. However, the water in the tank should be changed often enough to keep it clean and free from objectionable odors.

The quantity of water in the storage tank, expressed in pounds of water per gallon of milk stored, ranged from 14 to 68 pounds[4] for the 22 outfits (table 4). The reason for this wide variation is that the storage tanks are generally purchased with a capacity large enough to take care of the maximum milk production of the farm. At certain seasons of the year the production falls off, necessitating the addition of more water to the tank in order to have the milk can submerged

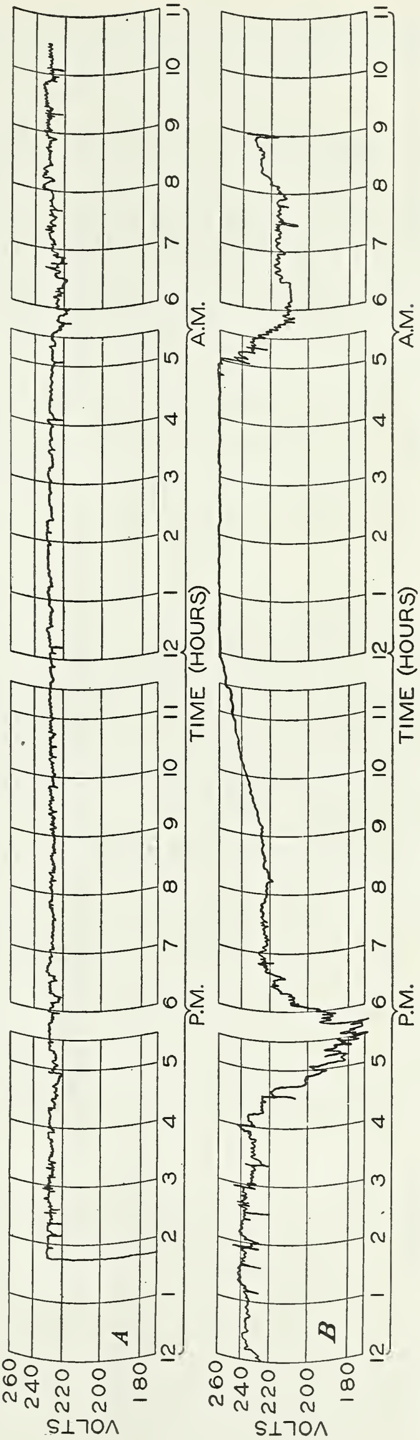

FIGURE 5.—Examples of line voltage on a country line serving dairy farms using mechanical refrigeration: *A*, Very uniform; *B*, extremely variable. Note the wide fluctuation in *B* at milk-cooling time.

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[4] One gallon of water weighs 8.33 pounds at 50° F.

to the neck in the cold water. Thus with a tank of given size, the less milk stored the more water is needed.

DATA ON OPERATION OF MACHINES

Of the 44 farms at which information was collected on use of small refrigerating machines, detailed observations of the operation of the machines were made at 34 farms, on air temperatures, storage temperatures, quantity of milk cooled, consumption of electric current, and running time. The data in table 5 and subsequent tables are based on observations taken over a period of 7 to 12 days at each of the 34 farms during the hottest months of the year. These data were obtained by installing tested watt-hour meters and recording thermometers at the farms, and instructing the dairymen in making temperature observations on the milk with a tested thermometer. This procedure was adopted because it was reasoned that if a mechanical outfit would function satisfactorily during the warmest months, it would do its work adequately in cooler weather. The average age of the machines on which observations were made was 1 year 6 months, with a range in age of from 1 month to 5 years 2 months.

RUNNING TIME PER DAY

The approximate running time of the refrigerating machines, shown in table 5, was calculated as follows: (1) The number of revolutions of the meter disk per minute was multiplied by the meter constant [5] and by 60 minutes to determine the rate of power consumption of the motor in watt-hours; (2) the number of kilowatt-hours a day registered on the meter was divided by the calculated rate of power consumption in kilowatt-hours while the motor runs an hour.[6] Since the number of kilowatts used per hour was so small that it could not be read directly from the meter dial, it had to be calculated from the revolutions per minute of the meter disk and the meter constant.

For example, a watt-hour meter rated by the manufacturer as having a meter constant of 2.5, registered 8 kilowatt-hours during a day and the average of several counts of the number of revolutions per minute of the meter disk was 5. Then the current used per hour would be: $5 \times 2.5 \times 60 = 750$ watt-hours [6] or 0.75 kilowatt-hour. The running time would then be $8 \div 0.75 = 10.7$ hours a day. The running time figured by this method of calculation was checked against the actually measured running time for several machines and found to be correct within 2 or 3 percent.

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[5] The meter constant is the number of watt-hours registered by one revolution of the meter disk.

[6] Due to the fact that power consumption is sometimes small, watt-hours are used throughout this circular instead of kilowatt-hours. Watt-hours can be converted to kilowatt-hours by dividing by 1,000.

TABLE 5.—*Data from 34 outfits showing average air temperature, average storage temperature, milk cooled, number of hours compressor motor was running, and consumption of electric current per 24-hour day over a period of 7 to 12 days in summer*

Group and farm no.	Average air temperature	Average tank or box temperature	Milk				Consumption of electric current			Average running time per day
			Average temperature to which cooled	Average degrees cooled	Average gallons cooled per day	Average refrigeration daily	Average daily	Average per gallon-degree of refrigeration	Average per gallon cooled per day	
Group 1, commercial tank, wet storage:	°*F.*	°*F.*	°*F.*	°*F.*	*Number*	*Gallon-degrees*	*Watt-hours*	*Watt-hours*	*Watt-hours*	*Hours*
1	75	38	43	31	60	1, 860	5, 429	2. 9	90. 5	12
2	73	36	41	28	15	420	2, 571	6. 1	171. 0	6
3	76	41	45	50	19	950	3, 727	3. 9	196. 1	9
4	80	40	44	15	101	1, 515	8, 857	5. 8	87. 7	12
5	82	48	48	47	25	1, 175	5, 429	4. 6	217. 1	16
6	77	36	38	24	75	1, 800	10, 333	5. 7	138. 0	8
7	77	40	44	39	47	1, 833	5, 350	2. 9	114. 6	12
8	81	43	43	15	64	960	5, 200	5. 4	81. 2	9
9	78	37	43	21	43	903	4, 444	4. 9	103. 0	12
10	75	49	48	22	107	2, 354	10, 250	4. 4	95. 8	24
11	82	40	42	55	52	2, 860	8, 250	2. 9	158. 6	11
12	73	34	42	29	43	1, 247	4, 000	3. 2	93. 0	10
13	78	41	42	21	74	1, 554	7, 888	5. 1	106. 0	12
14	77	42	46	17	123	2, 091	8, 556	4. 1	69. 6	14
15	79	40	44	21	83	1, 743	10, 800	6. 2	130. 0	10
Average [1]	78	40	44	29	62	1, 551	6, 739	4. 5	124	11. 8
Group 2, farm-built tank, wet storage:										
16	73	40	45	14	150	2, 100	11, 143	5. 3	74. 3	13
17	80	36	36	31	43	1, 333	8, 875	6. 7	206. 0	18
18	79	39	40	22	32	704	4, 818	6. 8	150. 0	10
19	63	41	44	55	68	3, 740	6, 667	1. 8	98. 0	8
20	76	43	44	51	53	2, 703	6, 429	2. 4	121. 1	9
21	80	37	37	21	46	966	3, 571	3. 7	77. 6	9
22	77	45	45	20	114	2, 280	6, 571	2. 9	57. 6	15
23	79	40	42	20	65	1, 300	6, 750	5. 2	104. 0	17
24	63	36	41	18	90	1, 620	6, 555	4. 0	72. 8	9
25	77	43	41	24	93	2, 232	9, 875	4. 4	106. 0	12
26	74	42	46	15	107	1, 605	10, 000	6. 2	93. 4	13
27	85	43	47	14	94	1, 316	9, 125	6. 9	97. 1	15
Average [1]	75	40	42	25	80	1, 825	7, 532	4. 7	105	12. 3
Group 3, dry-box storage:										
28	78	44	37	22	71	1, 562	7, 333	4. 7	103	12
29	80	37	39	30	121	3, 630	15, 833	4. 4	131	19
30	47	34	37	25	86	2, 150	10, 000	4. 7	116	6
31	73	40	44	48	56	2, 688	12, 667	4. 7	226	13
32	73	41	39	21	199	4, 179	24, 833	5. 9	125	18
33	75	39	36	20	200	4, 000	28, 750	7. 2	144	23
34	84	42	43	25	47	1, 175	10, 909	9. 3	232	17
Average [1]	73	40	39	27	111	2, 769	15, 761	5. 8	154	15. 4
Average [1] of groups 1 and 2	77	40	43	27	70	1, 673	7, 091	4. 6	115	12. 0
Average [1] of all groups	76	40	42	27	78	1, 898	8, 876	4. 9	123	12. 7

[1] Average of averages.

The time that a machine will run each day is an important factor to be considered in selecting refrigerating equipment for the farm. So far as power requirements are concerned, a machine that runs 24 hours a day may use no more current than one that runs only part of the day. This is shown by comparing the results for the machine on farm no. 10 with that on no. 14, where the running times were 24 hours and 14 hours, respectively, and the power used per gallon-degree of refrigeration was 4.4 and 4.1 watt-hours. However, the machine on farm 10, although working continuously, cooled the milk to only 48° F., which is barely low enough to meet the market conditions. Under such conditions, any power failure, break-down, or increase in the amount of milk to be cooled would make proper cooling difficult. Then, too, small refrigerating units are not designed for continuous operation, and the life of an overworked machine is comparatively short.

In this test there were so many variable factors affecting the running time and power consumption of each machine that it is difficult to determine definitely the effect of any one factor. However, in general, the results in table 5 indicate that a machine performing its work by running 8 to 10 hours a day is more economical than one running more than 14 hours.

Ten of the machines in groups 1 and 2 ran from 8 to 10 hours and averaged 9.1 hours daily, cooling 57.3 gallons of milk over a range varying from 18° to 55° F., and using 4.3 watt-hours per gallon-degree or 118 watt-hours per gallon cooled. Six machines in groups 1 and 2 ran over 14 hours and averaged 17.5 hours daily, cooling 75 gallons of milk 26° to 44°, using 5.1 watts per gallon-degree or 130 watt-hours per gallon-degree cooled. On comparing these two groups the advantage is seen to be with the machines running the shorter time. These 10 machines on an average cooled less milk per day but to a lower temperature, and used less power per gallon-degree of refrigeration, than the six running longer periods.

The time the machines operated per day was not affected noticeably by the temperature to which the milk was cooled. The data in table 5 show very little relationship between cooling temperature and running time. The differences found cannot be explained except by considering all factors in each case.

POWER CONSUMPTION

In the following paragraphs the conditions on individual farms are compared to bring out the things that seem to govern the power consumption on different farms. No dominant factor is shown for all machines; each case has its own special conditions that govern the power consumption per gallon-degree of refrigeration.

The machines on farms nos. 21 and 22 were identical in all respects, yet the former machine used 3.7 watt-hours per gallon-degree of refrigeration, and the latter used 2.9 watt-hours (table 5). This difference in consumption of electric current is best explained by a study of the separate factors on each farm. On farm no. 21 the milk was cooled to a lower temperature through a greater range in temperature. There was 2.5 times as much milk cooled on farm no. 22 as on no. 21, while the power consumption was about 1.8 times that of machine no. 21. The air temperature was 80° F. and the tank temperature 37° on farm no. 21, while on no. 22 the air temperature was 77° and the tank temperature 45°. In the case of these two machines it is shown that the most economical use of the tank was obtained when operated close to capacity and the tank temperature was not too low. The same relationship is seen in the power consumption per gallon of milk cooled, farm no. 21 using about 78 watt-hours and farm no. 22 about 58 watt-hours per gallon. The economy of operation of a machine should be measured by the power used, both per gallon-degree of refrigeration and per gallon of milk cooled. If the milk is cooled from body temperature to tank temperature by the refrigerating machine alone, the power consumption is low per gallon-degree but high per gallon cooled.

On farms nos. 5, 11, and 20, where the temperature drop ranged from 47° to 55°, the power consumption was high per gallon cooled, and low for each gallon-degree of refrigeration. Farms nos. 4, 26, and 27 used well water to precool the milk so that the machine cooled it just 15°. Here the power consumption was low per gallon cooled and high per gallon-degree. The greater amount of milk cooled on farms nos. 4, 26, and 27 would also help to decrease the power consumption per gallon, even though the average tank temperature was lower than on the other three farms, because a machine working at capacity tends to use less power per gallon.

A comparison of the results on farms nos. 7 and 15 (table 5) shows that the machine on farm no. 7 was operated more economically, cooling 47 gallons of milk through a range of 39°, than that on no. 15, cooling 83 gallons of milk through 21°. The tank temperature was the same in each case, and the air temperature was only 2° higher at farm no. 15. Here the factors that affect the power consumption most are insulation and capacity. These two factors are hard to separate, since it was impossible in most cases to determine the refrigeration loss accurately or to observe the condition of the insulation in the tanks. The tank on farm no. 7 showed a heat loss of 28 percent, and that on farm no. 15 showed a loss of 43 percent. Tank no. 7 was factory built with 2-inch cork insulation and 72 square feet of exposed surface. No. 15 tank was home constructed with 3-inch cork insulation, but had 116 square feet of surface exposed. The high percentage of refrigeration loss from tank no. 15 was due largely to its being used at less than capacity; and perhaps to damp insulation, which would increase the amount of heat absorbed from the outside air.

REFRIGERATION LOSS FROM STORAGE TANK OR BOX

In most of the storage units tested the refrigeration loss from the tank or box was approximately determined to be less than 50 percent of the total refrigeration supplied by the refrigerating unit. From general experience a well-constructed, well-insulated tank or box cooling its capacity of milk, should have a refrigeration loss of less than 30 percent. The refrigeration loss for the different units included in this study ranged from about 23 to 66 percent. On farms nos. 4, 6, 13, 18, 19, and 21, where the loss was determined by cooling the tanks with ice for a short time, it was 43, 49, 60, 59, 29, and 66 percent, respectively, of the total refrigeration. Those having a large percentage of loss were being used at a low capacity.

COMPARISON OF FARM-BUILT AND COMMERCIALLY MANUFACTURED TANKS

Comparison of the results obtained with farm-built tanks and commercially manufactured tanks (table 5) shows that farm-built tanks were about as efficient as manufactured tanks. However, an important factor to bear in mind is that all home-built tanks contained 1 inch more cork board than the commercial tanks.

COMPARISON OF WET-TANK AND DRY-BOX STORAGE

In comparing the results for dry-box storage with those for wet-tank storage (table 5) attention is called to the fact that with dry storage there was an average of 111 gallons of milk cooled per day as against 70 gallons with wet storage. However, the average running time per day was 15.4 hours, as against 12 hours with wet storage. The average power consumption per gallon of milk cooled was 5.8 watt-hours with dry storage, and 4.6 watt-hours with wet storage. From these data it is apparent that dry storage costs slightly more. However, one fact to be kept in mind is that it is possible to cool to lower temperatures with dry storage, because the brine is held at a temperature below freezing, whereas storage water if held below freezing would form ice and could not be circulated through the milk cooler.

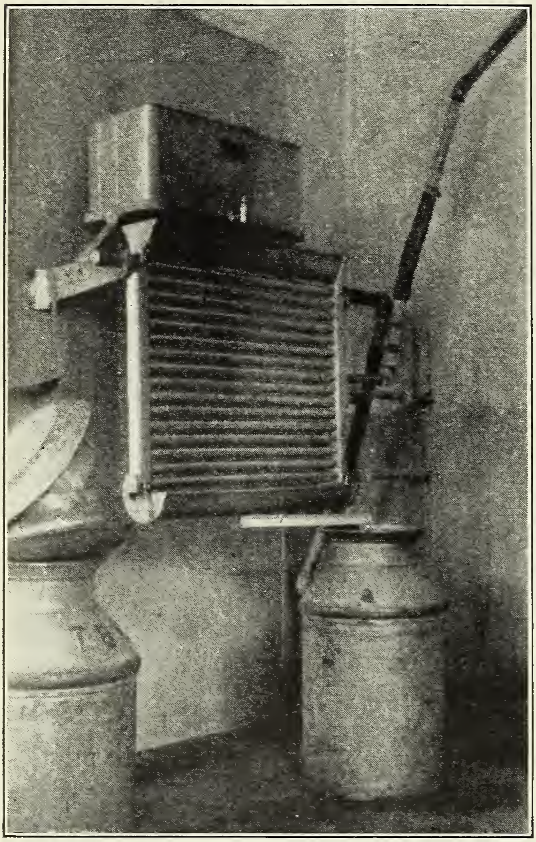


FIGURE 6.—Milk cooler with pipes arranged for running water through upper half and either tank water or brine through lower half.

PRECOOLING MILK IN WET-TANK STORAGE

The outfits studied were divided into three groups according to the source and method of using the water going through the milk cooler: (1) Cold water from storage tank; (2) well water through upper half of cooler, cold water from storage tank through lower half of cooler (fig. 6); and (3) well water alone. Table 6 gives complete data on 28 farms, using wet-tank storage, which are grouped according to these combinations of precooling. As stated before, there are so many variable factors that it is hard to show definite conclusions for any one factor. However, the effect of using well water can be noted from the electric current used per gallon, running time per gallon, and the rise in the storage-tank temperature. The 6 farms using tank water alone average about 152 watt-hours per gallon cooled, and the average rise in temperature of the tank was 4.3°; while the 19 farms using well water through the upper part of the cooler and tank water through the lower half averaged about 104 watt-hours per gallon cooled, and the rise in tank temperature was 2.8°. This is a difference of 48 watt-hours per gallon cooled and 1.5° in rise of tank temperature. The average running time per gallon for the 6 farms using no well water was 19 minutes; while the average running time for the 19 farms using well water through the upper half of the cooler was but 11 minutes, a difference of 8 minutes per gallon.

Table 6.—*Data from 28 farms showing results obtained with refrigerating machines and storage tanks, where a surface cooler was used with cold tank water alone, well water and tank water, and well water alone for cooling the milk over the surface cooler*

Group and farm no.	Average air temperature	Average storage-tank temperature	Milk				Consumption of electric current			Average running time per gallon	Average rise in storage tank at cooling time
			Average temperature to which cooled	Average degrees cooled	Average gallons cooled per day	Average refrigeration daily	Average daily	Average per gallon-degree of refrigeration	Average per gallon cooled per day		
Group 1, used cold water from tank:	*°F.*	*°F.*	*°F.*	*°F.*	*Number*	*Gallon-degrees*	*Watt-hours*	*Watt-hours*	*Watt-hours*	*Min.*	*°F.*
3	76	41	45	50	19	950	3, 727	3. 9	196. 1	28	2. 3
5	82	48	48	47	25	1, 175	5, 429	4. 6	217. 0	38	4. 2
7	76	40	44	51	46	2, 346	5, 500	2. 3	119. 5	15	6. 0
11	82	40	42	55	52	2, 860	8, 250	2. 9	158. 6	13	4. 9
19	63	41	44	55	68	3, 740	6, 667	1. 8	98. 0	7	3. 4
20	76	43	44	51	53	2, 703	6, 429	2. 4	121. 1	10	5. 2
Average	76	42	44	52	44	2, 296	6, 000	3. 0	151. 7	19	4. 3
Group 2, used well water and water from storage tank:											
1	75	38	43	31	60	1, 860	5, 429	2. 9	90. 5	12	2. 6
2	73	36	41	28	15	420	2, 571	6. 1	171. 0	24	1. 5
4	80	40	44	15	101	1, 515	8, 857	5. 8	87. 7	7	. 8
6	77	36	38	24	75	1, 800	10, 333	5. 7	138. 0	6	2. 0
7	78	40	44	27	48	1, 296	5, 200	4. 0	109. 3	14	3. 1
8	81	43	43	15	64	960	5, 200	5. 4	81. 2	8	8. 1
9	78	37	43	21	43	903	4, 444	4. 9	103. 0	17	3. 1
10	75	49	48	22	107	2, 354	10, 250	4. 4	95. 8	13	1. 3
12	73	34	42	29	43	1, 247	4, 000	3. 2	93. 0	14	1. 8
13	78	41	42	21	74	1, 554	7, 888	5. 1	106. 0	10	3. 5
14	77	42	46	17	123	2, 091	8, 556	4. 1	69. 6	7	2. 4
15	79	40	44	21	83	1, 743	10, 800	6. 2	130. 0	7	1. 3
16	73	40	45	14	150	2, 100	11, 143	5. 3	74. 3	5	6. 8
18	79	39	40	22	32	704	4, 818	6. 8	150. 0	19	1. 7
23	79	40	42	20	65	1, 300	6, 750	5. 2	104. 0	17	2. 7
24	63	36	41	18	90	1, 620	6, 555	4. 0	72. 8	6	4. 7
25	77	43	41	24	93	2, 232	9, 875	4. 4	106. 0	8	2. 9
26	74	42	46	15	107	1, 605	10, 000	6. 2	93. 4	7	2. 0
27	85	43	47	14	94	1, 316	9, 125	6. 9	97. 1	9	1. 2
Average	77	40	43	21	77	1, 506	7, 463	5. 1	103. 8	11	2. 8
Group 3, used well water alone:											
17	80	36	36	31	43	1, 333	8, 875	6. 7	206. 0	25	1. 1
21	80	37	37	21	46	966	3, 571	3. 7	77. 6	12	. 1
22	77	45	45	20	114	2, 280	6, 571	2. 9	57. 6	8	0
Average	79	39	39	24	68	1, 526	6, 339	4. 4	113. 7	15	. 4

Further comparisons can be made of some of the individual outfits. For example, on farms 2 and 3 the conditions were identical as regards machine used, storage tank, housing conditions, insulation, and handling of product. Farm 3 cooled under higher air temperature, carried a higher storage temperature, and cooled more gallons of milk, but the average temperature to which all the milk was cooled was not as low. However, as far as refrigeration is concerned, farm 2 compensated for the higher air temperature and greater volume of milk by cooling to and storing at a lower temperature. Farm 3, using no well water, consumed about 196 watt-hours per gallon of milk cooled, with a running time of 28 minutes per gallon and a rise in storage-tank temperature at cooling time of 2.3°; while farm 2, using well water through the upper half of the cooler, consumed 171 watt-hours per gallon cooled, with a running time of 24 minutes per gallon and a rise in storage-tank temperature of 1.5°. Thus on farm 3, using no well water, the power consumption per gallon was 14.6 percent higher, the running time per gallon was 16.6 percent longer, and the rise in temperature of the tank storage water at cooling time was 53 percent more than on farm 2.

As will be noted, farm 7 appears in both group 1 and group 2 of table 6. At this farm two different methods of cooling were used for a period of a week each. All conditions were as nearly alike as possible under actual farm conditions. One week the night's milk was cooled by pumping well water only through the cooler, after which it was placed in the storage tank. The morning's milk was cooled by pumping well water through the upper half of the cooler, and storage-tank water through the lower half. The other week no well water was used. The night's milk was set into the tank as soon as the can was full; the morning's milk was cooled by pumping storage-tank water only through the cooler. In the first case (group 2) there was consumed about 109 watt-hours per gallon cooled, the machine ran 14 minutes per gallon-cooled, and there was a rise in tank temperature of 3.1°. In the second case, there was consumed about 120 watt-hours per gallon cooled, the machine ran 15 minutes per gallon cooled, and there was a rise in tank temperature of 6°. This was an increase of about 10 percent in power consumption per gallon, 7 percent more running time, and a 94-percent rise in tank temperature at cooling time. In other words, the use of well water helps materially to lower the cost of operation and will enable a machine to carry a heavier load than is possible without its use.

Where well water alone was used through the milk cooler (group 3, table 6), the averages are somewhat higher than in group 2. This was due to the fact that the machine on farm no. 17 had been used a long time and was inefficient. There should be slightly lower consumption of current and slightly less running time where well water alone is used for preliminary cooling, due to no heat losses from the tank water through radiation and friction. However, this system is not always practical, as most farms usually are unable to store their morning's milk a sufficient time to lower its temperature to a point where it meets the market requirements.

COMPARISON OF MECHANICAL REFRIGERATION WITH ICE

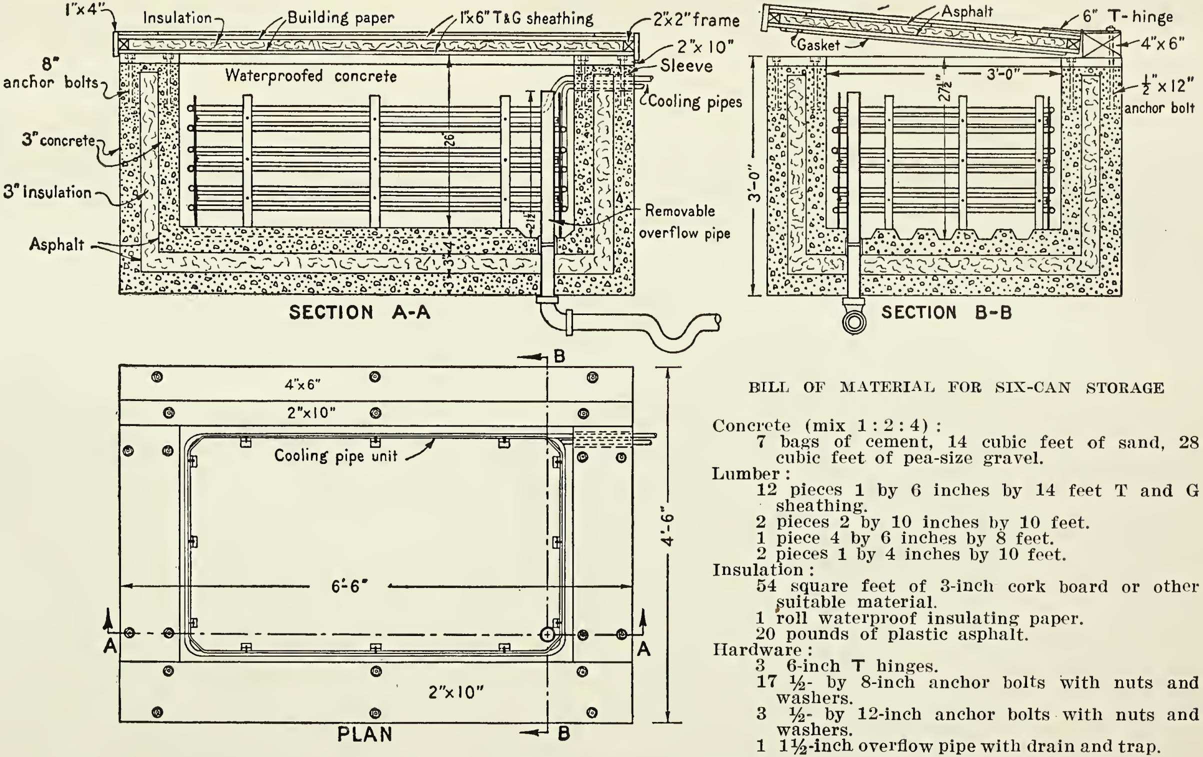
In order to show a comparison between ice and the mechanical outfits and to give an idea of what might be expected under farm conditions, the use of the machine was discontinued on six farms and ice substituted for periods of 3 or 4 days. Enough ice was kept in the tanks to maintain, as nearly as possible, the temperature used with the machines. The results for these six farms are presented in table 7.

Air temperatures, amount of milk cooled, temperature to which cooled, number of degrees cooled, and individuality of the machines are all variable factors which determine the power used per gallon-degree cooled. An additional factor when ice is used is the promptness of the iceman in servicing the tanks. For these reasons it is practically impossible to compare the individual farms. However, in looking at the averages of the six farms, it is noted that the average daily air temperature is the same with ice as with the machines. The average storage-tank temperature, the average number of gallons cooled, the average temperature to which cooled, and the average number of degrees cooled are quite close, so that there is a difference of only 64 gallon-degrees between the ice and machines. These figures show that it took 4.8 watt-hours of electricity or 0.123 pound of ice to cool 1 gallon through 1° F. and to hold the average storage temperature of about 39°. If the cost of ice to these farmers was 40 cents per 100 pounds, the cost of electricity was 3½ cents per kilowatt-hour, and their period of warmest weather was 7 months, the average cost of the electricity on each of these six farms would be $110 less than the cost of the ice. No conclusions can be drawn as to whether this amount is sufficient to take care of interest, depreciation, and repairs on the mechanical units.

PLANS FOR BUILDING A STORAGE TANK OR A BOX

The drawings shown in figure 7 give the plans in detail for the construction of a storage tank. This is an insulated concrete tank with an insulated wood cover. Several different kinds of insulation, loose or in waterproof packages may be used, of which cork board has been the most popular. Regardless of the insulation used, care must be taken to have it covered thoroughly with asphalt to prevent the entrance of moisture, since the insulating value of any material is greatly decreased if it becomes wet. The bottom of the tank may be made smooth instead of ridged as shown, but in that case the cans should be set on a grating made of water-resisting wood to permit the circulation of water around the cans. The number and size of the coils and the size of the compressor unit depend on the maximum quantity of milk to be cooled daily and the number of degrees through which the milk is to be cooled.

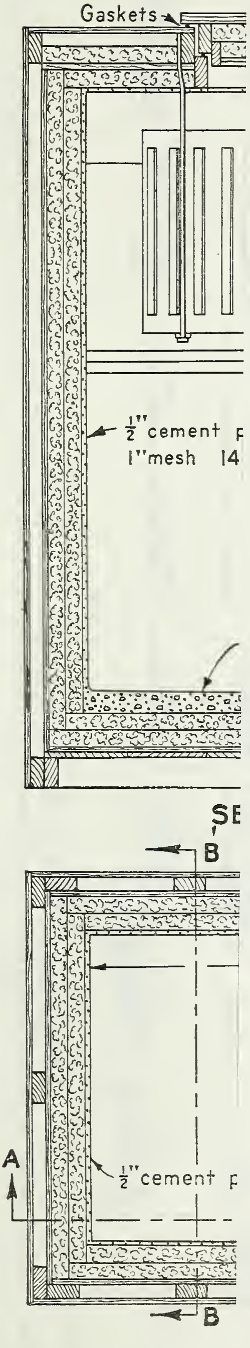
The dry box shown in figure 8 has been designed primarily for use on dairy farms bottling milk. If the milk is to be stored in cans, the box will take care of a much larger quantity of milk than if it were stored in bottles, and care should be taken to have a compressor and a brine tank large enough to supply the total amount of refrigera-



BILL OF MATERIAL FOR SIX-CAN STORAGE

Concrete (mix 1 : 2 : 4) :
  7 bags of cement, 14 cubic feet of sand, 28 cubic feet of pea-size gravel.
Lumber :
  12 pieces 1 by 6 inches by 14 feet T and G sheathing.
  2 pieces 2 by 10 inches by 10 feet.
  1 piece 4 by 6 inches by 8 feet.
  2 pieces 1 by 4 inches by 10 feet.
Insulation :
  54 square feet of 3-inch cork board or other suitable material.
  1 roll waterproof insulating paper.
  20 pounds of plastic asphalt.
Hardware :
  3 6-inch T hinges.
  17 ½- by 8-inch anchor bolts with nuts and washers.
  3 ½- by 12-inch anchor bolts with nuts and washers.
  1 1½-inch overflow pipe with drain and trap.

FIGURE 7.—Plan for constructing a storage tank.



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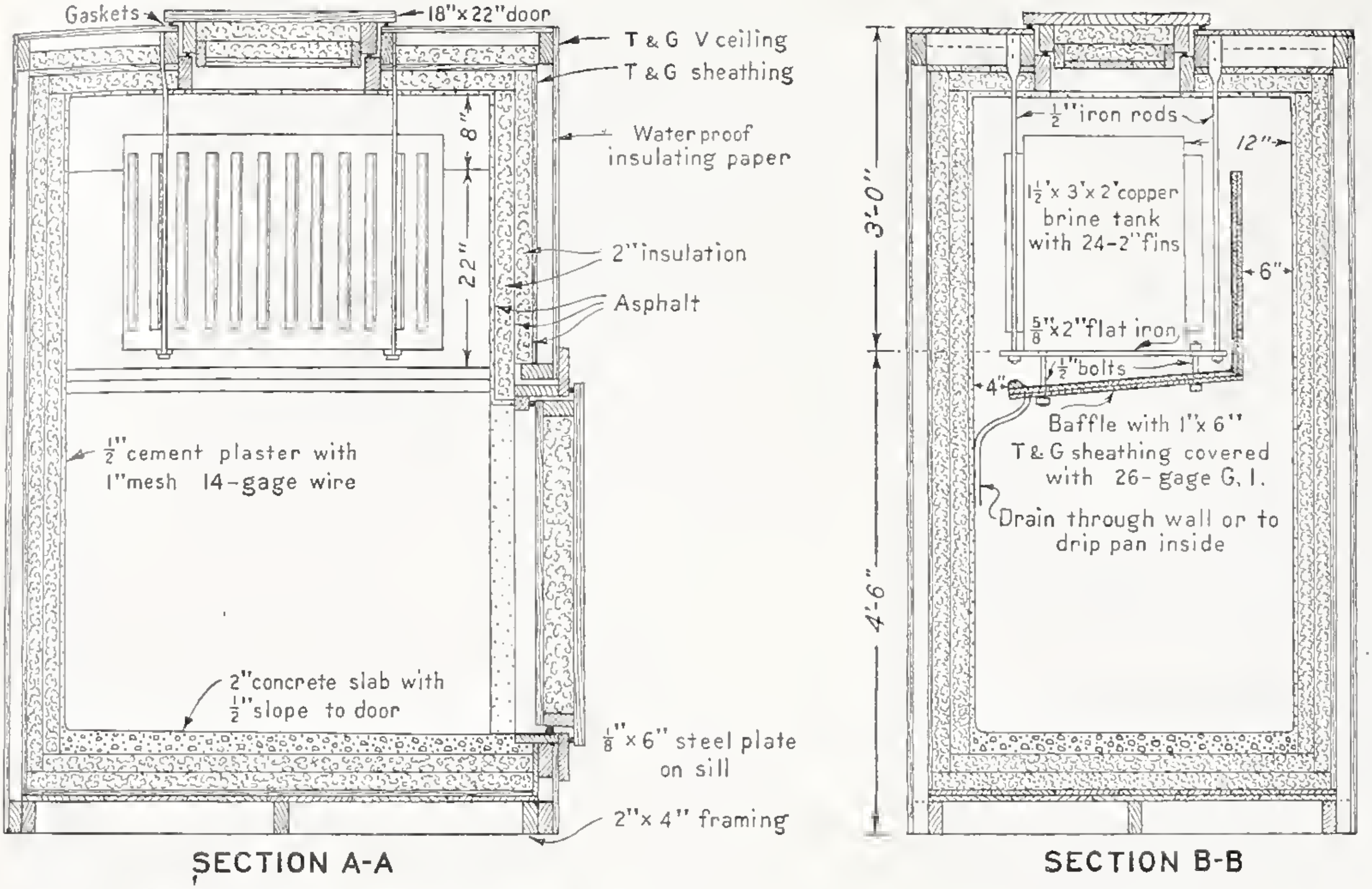
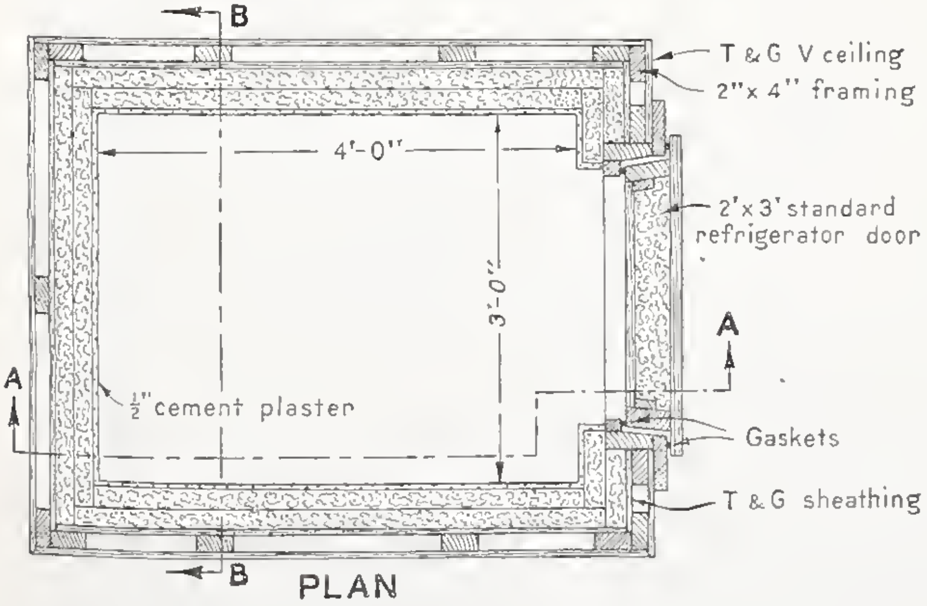

Gaskets
18"x22" door
T & G V ceiling
T & G sheathing
Waterproof insulating paper
8"
22"
2" insulation
Asphalt
½" cement plaster with 1" mesh 14-gage wire
2" concrete slab with ½" slope to door
⅛" x 6" steel plate on sill
2" x 4" framing
SECTION A-A
3'-0"
4'-6"
½" iron rods
12"
1½' x 3' x 2' copper brine tank with 24-2" fins
6"
⅝" x 2" flat iron
½" bolts
4"
Baffle with 1" x 6" T & G sheathing covered with 26-gage G. I.
Drain through wall or to drip pan inside
SECTION B-B



BILL OF MATERIAL FOR STORAGE OF 50 GALLONS IN QUART BOTTLES

Concrete (mix 1 : 1½ : 3):
1 bag cement, 1½ cubic feet sand, 3 cubic feet gravel.

Plaster:
3 bags cement, 4 cubic feet sand.

Lumber:

250	board-feet, 1- by 6-inch T and G sheathing.
200	board-feet, tongue-and-groove V ceiling.
15	pieces 2 by 4 inches by 8 feet.
15	pieces 2 by 4 inches by 10 feet.

Miscellaneous:

50	pounds of plastic asphalt.
250	square feet of 2-inch cork board or other suitable insulating material.
2	rolls waterproof insulating paper.
1	2- by 3-foot standard refrigerator door and equipment.
4	½- by 40-inch iron rods, threaded on one end.
2	½- by 8-inch machine bolts, with nuts and washers.
4	⅝- by 2-inch iron flats, 26 inches long.
20	square feet no. 26-gage galvanized iron.
1	¾-inch drainpipe, length as required.

FIGURE 8.—Plan for constructing a storage box.

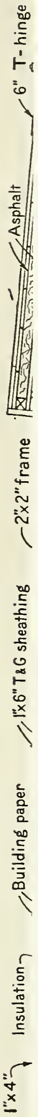

1"x4"
Insulation
Building paper
1"x6" T&G sheathing
2"x2" frame
Asphalt
6" T-hinge

TABLE 7.—*Comparison of ice with machines on same farms showing the average air temperature, storage temperature, refrigeration per day, current and pounds of ice used per gallon-degree, and per gallon of milk cooled*

Farm no.	Average air temperature when using—		Average daily storage-tank temperature		Milk								Power used per gallon-degree	Ice used per gallon-degree	Power used per gallon cooled	Ice used per gallon-cooled
					Average temperature to which cooled		Average degrees cooled		Average gallons cooled per day		Average refrigeration per day					
	Machine	Ice	Machine	Ice	Machine	Ice	Machine	Ice	Machine	Ice	Machine	Ice				
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Number*	*Number*	*Gallon-degrees*	*Gallon-degrees*	*Watt-hours*	*Pounds*	*Watt-hours*	*Pounds*
4	80	80	40	37	44	46	15	15	102	101	1,530	1,515	5.8	0.098	87.7	1.5
6	77	76	36	40	38	40	24	23	75	69	1,800	1,587	5.7	.124	138.0	2.9
13	78	69	41	38	42	42	21	20	74	68	1,554	1,360	5.1	.137	106.0	2.8
18	79	81	39	40	40	41	22	24	32	38	704	912	6.8	.135	150.0	3.2
19	63	64	41	44	44	44	55	52	68	70	3,740	3,640	1.8	.080	98.0	4.1
21	80	85	37	38	37	38	21	20	46	45	966	900	3.7	.166	77.6	3 3
Average	76	76	39.0	39.5	40.8	41.8	26.3	25.7	66.2	65.2	1,716	1,652	4.8	.123	109.6	3 0

tion in 10 or 12 hours, and to cool the milk to the desired storage temperature in the time that it is allowed to run over the surface cooler. The drawings show the inside walls of the box finished with cement plaster. If it is desired, wood sheathing may be placed inside of the insulation and covered with no. 26-gage galvanized iron. Care must be taken to have all joints soldered. A direct expansion coil can be substituted for the brine tank in the storage box, if a direct expansion surface cooler is to be used.

SUMMARY AND CONCLUSIONS

A refrigerating machine for cooling and storing milk on the dairy farm should be of such size that the compressor will not have to run over 14 hours per day, if efficiency of operation is to be assured.

The average cost of complete outfits on 23 farms was about $7.69 per gallon of milk storage, and the average cost per 10-gallon can of rated storage capacity ranged from $48 to $103, the lower cost being for larger storage capacity.

Care should be taken to locate the compressor outside the milk-handling room and where it will have good circulation of air.

The cost of repairs on 19 farms averaged $4.20 per year.

Care should be taken to keep the water in the storage tank clean.

The amount of water in the storage tank will vary according to the amount of milk cooled.

The amount of coil to use per cubic foot of tank will vary according to the amount of milk to be cooled and stored per 24 hours; the range of temperature through which the milk will be cooled; the temperature of the well water used through the surface cooler; and the thickness of the tank insulation.

Bunched coils are difficult to support rigidly, and ice forms on them easily.

Line voltage may vary greatly on country lines, and if service connections are too light may cause motor-starting troubles.

Machines running on an average of 9.1 hours per day used less power per gallon of milk cooled and per gallon-degree of refrigeration than machines running on an average of 17.5 hours per day.

A well-constructed, well-insulated storage box cooling to capacity should have a refrigeration loss of less than 30 percent.

Home-built tanks observed were as efficient as commercially manufactured tanks, but carried more insulation.

The power consumption is higher with dry-box storage than with wet-tank storage, but lower temperatures are possible with a dry box.

Well water used through the upper half of the cooler will lessen the load on the mechanical outfit, and allow it to care for more milk.

Cost of power was less than cost of ice; however, no data were available on depreciation, so this factor, and interest and repairs, are not taken into consideration in this comparison.

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